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BINDERS IN MOIST FEEDS FOR FISH

(Bindemidler i Våtfor til Fisk)

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1. Introduction.

In the aquatic environment where fish aquaculture is being carried out, feed utilization can become substantially lowered if much of the feed is wasted. Poor binding ability in the feed can make it difficult to get the feed into the fish without small particles breaking loose and get lost in the feeding frenzy.

In addition to poorer feed utilization, wasted feed also lowers the oxygen holding capacity of the water and the growth potential of the fish.

Under poor conditions the feed waste can comprise more than half of the feed supplied.

In fish farms in less favorable locations (poor current conditions, short distance between net bag (pen) and the bottom, bottom sills in the farm area etc.), large feed losses together with excrements can result in large accumulations under the pens. These piles regularly give off gases produced by bacteria that will reduce the production volume (capacity) of the installation.

Occasionally gas pockets will form in the waste piles and these can suddenly burst and cause considerable fish mortality.

The normal consumption of moist feed under actual practice is today about 6 kg feed per kg live fish , and for moist pellets the feed factor is around 3.

Calculations of protein- and energy contents in commonly used feed mixtures indicate that half the amount of feed should be sufficient to produce 1 kg farmed fish. The reason for this excessive use of feed is mostly feed waste. The rest is due to overfeeding and poorly balanced moist feed mixtures.

The market prices for salmon and trout have until recently been favorable so that a relatively high feed wastage could be tolerated economically.

The large decline in salmon prices lately indicates that feed utilization must be improved in order to maintain the

profitability in the fish farming industry.

A much lower waste of feed with moist feeds and moist p.2
pellets can be achieved with the addition of suitable commercial binders. The consistency of the feed will thus be better and a larger part of the diet will be utilized by the fish.

The objective of the project was to find suitable binders that will make moist feeds and moist pellets more attractive. With this as the background, studies have been carried out on factors that will reduce feed costs and at the same time result in good growth.

In order for a binder to be used it must give the feed a good consistency when being produced and when being fed. The binder must also reduce feed waste to a considerable degree, and it must have little or no effect on the feed uptake of the fish.

The project received a number of different binders that could be of interest for use in wet feed for fish. In order to choose the most suitable of these, both subjective and objective experiments were performed. Greatest emphasis was placed on the objective measurements that included consistency (texture) measurements with penetrometer, and digestibility and growth trials.

The experiments also included a separate part for trials with binders for acid silage feeds.

2. ON BINDERS IN GENERAL p.3

Binders that very often are polymeric polysaccharides, are indigestible or poorly digestible for fish. Binders are therefore only included as a component to improve the consistency of the wet feed. Their positive effects must be found in the form of reduced feed waste, less pollution and therefore better utilization of the feed.

The various types of binders that are available at relatively reasonable prices are mostly found in the main chemical groups guar gum, cellulose derivatives and alginates.

Solutions of binders can be decomposed bacteriologically. This can be prevented through the addition of preservatives like sodium benzoate, citric acid, sorbic acid etc.

2.1. Guar gum.

Guar gum is produced from the seeds of the legume guar (Cyanaposis tetragonolobus) which has been cultivated for a long time in India and Pakistan.

This binder is much used both in the textile and the paper industry. Due to its consistency-improving properties, it has also gained inpass into the production of explosives and the feed industry in moist feeds. Guar gum is also used as a flocculant in the mining industry. In the food industry guar gum is used as an additive in processed cheeses, ice cream, baker's products (retains moisture and fat), meat products, sauces, fruit juices etc.

Guar gum is finely ground seed endosperm, but the feed-quality guar gum contains small remnants of seed coating and germ. Analyses of guar gum show the following average values:

Galactomannan	78-82%
Protein	4-5 %
Fibers	1.5-2.0%
Ash	0.5-0.9%
Fat,ether-extracted	0.5-0.8%
Water (moisture)	10-13%

Structurally guar gum (galactomannan) is composed of a straight skeleton of D-mannopyranosyl units where every second unit has a D-galactopyranosyl unit attached. (Fig. 1). Guar gum has an average molecular weight in the 200,000 to 300,000 range. p.4

The most important property of guar gum is the water binding ability. Even in cold water it can form very viscous solutions, and when higher concentrations are used, the solution becomes jellylike. The solutions are stable in a pH range of 1.0 to 10.5. This excellent stability is due to the unchanged molecular structure. The pH has no influence on the final viscosity, but the water binding ability is highest at pH 8-9 and lower when the pH is over 10 and under 4.

The water binding ability of guar gum is variable. Usually a reaction time of about 2 hours is expected to achieve close to maximum viscosity.

A solution in water with 1% guar gum of good quality has a viscosity of 3000 - 6000 centipoises (cps) *) The viscosity is doubled when the addition of gum is doubled from 1% to 2%. A guar gum solution prepared at higher temperatures will reach maximum viscosity faster than a solution prepared at lower temperatures. The highest viscosity in guar gum preparations is reached at temperatures around 25° - 40°C.

The stability is good in gum solutions with salts containing mono-, di-, or trivalent cations. The viscosity increases with increasing amounts of these salts. The effect of anions such as nitrates, chlorides and sulfates will likewise increase the viscosity in guar gum solutions. Many polyvalent cations, such as calcium, aluminum and chromium , will make guar gum insoluble in certain ranges of pH. Guar gum can be active when used with other binders such as alginate and carboxymethylcellulose.

The quality of the various types of guar gum varies considerably depending on production method, purity and particle size.

2.2. Cellulose derivatives

p.5

Cellulose derivatives are manufactured from cellulose found in its purest form in cotton fibre with 98& alpha cellulose on a dry weight basis. Wood pulp contains about 40 - 50% cellulose, and is the most important source of raw material for this type of thickeners and binders.Waste from agriculture such as straw, corn stalks etc. contain about 30% cellulose and are also used as raw materials.

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*) 1 centipoise= 10 newton-seconds/m

The cellulose molecule consists of a polymeric chain with repeating cellobiose units. These are again composed of two anhydro-glucose units (Fig. 2). The number of anhydroglycose units indicates the degree of polymerization of the cellulose.
Each anhydroglucose unit has three hydroxyl groups where substitution can take place (indicated with an R in the structural formula).
Common substitutions are as follows:

$HO-CH_2-CH_2-$	Hydroxyethyl- (HEC)
$NaOOC-CH_2-$	Sodium carboxymethyl- (CMC)
CH_3-	Methyl- (MC)
$CH_3-CH_2-O-CH_2-CH_2-$	Ethylhydroxyethyl- (EHEC)
$HO-CH_2-CH_2-CH_2-$	Hydroxypropyl- (HPC)

The degree of substitution indicates how many hydroxyl groups have been replaced per anhydroglycose unit. Theoretically it can be up to three, but practically this cannot be achieved.

The cellulose derivatives are long chain, polymeric compounds (polysaccharides) and the character of the solution depends both on the degree of polymerization and the degree of substitution of the compound. With increasing molecular weights, the viscosity in the solution of the cellulose derivative will increase.

Various cellulose compounds were tried in the experiments. (Table 4). Natrosol belongs to the ethylhydroxyethyl compound (EHEC), Blanose is substituted with carboxymethyl groups (CMC) and the Methocel products are hydroxypropyl derivatives.

The most commonly used derivative in both the food and the feed industries is sodiumcarboxymethylcellulose, often only called CMC. Most CMC products have a degree of substitution of 0.4 - 1.2 with a uniform distribution of carboxymethyl groups on the polymeric anhydroglycose chain. Due to the combination possibilities between the three variables; degree of substitution, distribution of the substitution groups and degree of polymerization, there are numerous products on the market. The viscosity of a 2% CMC- solution in water range from about 8 cps. p.6

to about 50,000 cps.

Solutions with low molecular CMC products that have low viscosities are less pseudoplastic than solutions with high viscosities.

Solutions with certain high molecular CMC products have thixotropic properties (free flowing when stirred, but more or less jellied or firm otherwise).

The viscosity in CMC solutions are temperature dependent and viscosity changes are reversible.

Stirring at high temperatures over longer periods will depolymerize CMC solutions and thus will lower the viscosity.

CMC solutions are quite stable between pH 5 - 10 with the greatest stability between pH 7 - 9. Below pH 5 the viscosity is lowered, and at pH lower than 3, precipitation of the carbomethoxy cellulose can occur.

Monovalent cations usually have no influence on the viscosity in CMC solutions. Some divalent cations can give opaque solutions, and trivalent cations like iron and aluminum form insoluble salts or gels.

In the food industry the cellulose derivatives are used as thickeners, binders and emulsifying- and suspensing agents. They are included in foods like salad dressings, diet foods, milk- and fruit drinks, marmalade etc.

The paint industry utilizes the derivatives as thickeners and they also act as a suspension medium for the pigments. In paint and varnish removers they form a gel with a solvent which can then act over a longer period without evaporating. p.7

Otherwise it can be mentioned that cellulose derivatives are used in printers ink, as thickeners in glue, as film formers for surface treatments in the paper industry etc.

2.3. Algin

Algin is a common designation for alginates that are salts of alginic acid. Algin is produced from seaweeds and kelp, where these compounds are found in cell walls. In Norway the raw

materials for alginates are mostly rockweed (Ascophyllum nodosum) and giant kelp (Laminaria hyperborea).

Alginic acid is not soluble in water, but its sodium, potassium , magnesium and ammonium salts are water - soluble and form a viscous solution. The viscosity is not solely determined by the concentration of the alginate, but is also dependent on the degree of polymerization of the alginate. The cation type and source of raw material for the alginate also plays a certain role. The molecular weights of alginates are in the range of 32,000 to 200,000.

The alginic acid molecule is in reality a mixed linear polymer of beta-D-Mannopyranosyluronic acid and alpha-L-Gulopyranosyluronic acid, both (1 - 4) -bound. See Figure 3.

In the same molecular chain the acids occur both separately in pure block segments and in alternating copolymeric segments.

In an alginate solution gels are usually formed through a gradual and uniform addition of either calcium - or hydrogen ions, or both at the same time.

The gelling mechanism of the alginates is based on a cross linking of the uronic acids with calcium or other polyvalent metallic ions (figure 4). The reaction can be intramolecular as well as intermolecular. In a complete reaction of a sodium alginate solution with calcium, a very stubborn insoluble calcium alginate is formed. The addition of smaller quantities of calcium makes the gel less firm. p.8

Alginates with di- or trivalent cations, except magnesium, are insoluble in water. On addition of water they only swell up.

The affinity to polyvalent metallic ions is dependent on the relative amounts of D- mannuronic - and L-guluronic acid units in the alginate. In different species of brown algae, and especially in young stands, the relative amounts of mannuronic acid and guluronic acid can be very different. In Laminaria digitata the M/G ratio can be 1.45 while the ratio in Laminaria hyperborea can be 0.45. Alginate from digitata has, for example greater affinity to cadmium than hyperborea alginate.

A high content of guluronic acid in an alginate solution gives a rapid gel formation after addition of relatively large amounts of calcium salts. In contrast, the changeover from solution to gel formation is slower when the alginate solution has a high content of mannuronic acid.

Different types of alginate powders are being produced today for very different end uses. These dry mixtures with finely ground, monovalent alginates (most often sodium compounds) also contain polyvalent mineral salts for gel formation in water solution (most often a calcium salt).

Gelling times and gel character are dependent on parameters like the ratio between the uronic acids in the algin, the solubility of the calcium salt, the degree of grinding (fineness) of the product, the addition of retardants like for instance sodium phosphate or sodium tetrapyrophosphate (they tie up calcium ions), addition of acid to improve the solubility of the calcium salt and thereby more rapid gelling, and not at least the amount of calcium and alginate in the solution.

A high viscosity algin has a viscosity of at least 2000 cps. at a concentration of 1% in water, while a very low viscosity alginate type can have a viscosity of under 10 cps. at the same concentration. p.9

The viscosity of an alginate solution decreases at increasing temperatures. If the warming takes place over a short time period, the solution will revert back to the original viscosity when being cooled to room temperature. If the solution is being heated for a longer period of time, it will be depolymerized and a lowering of the viscosity will take place. An alginate solution will increase in viscosity when being frozen and it will revert to the original viscosity upon thawing.

An alginate solution is stable between pH 4 and 10. At pH 3 the insoluble alginic acid will precipitate, and at a pH of more than 12 the solution becomes unstable (the viscosity will first increase, but will decrease on storage).

Alginates are utilized as thickeners, gels, films,

suspending agents and binders. Examples from various areas are: Ice cream (consistency and avoidance of ice crystals), yoghurt, processed cheeses, dessert puddings and jellies, diet mayonnaise and salads, sauces, soups, dog foods, binders for tablets, creams, teeth impression molds, welding electrodes, textile dyes, tooth paste, shoe polish, ore floatation, stabilizer for beer foam etc.

3. METHODS

p.10

Dry matter was determined by freeze drying. The samples were dried in a Hetosicc CD4-2 at 20°C to 0.05 - 0.01 Torr (Heto, Birkerød, Denmark)

Protein (N x 6.25) was determined by a modified Kjeldahl method (Crooke and Simpson, 1971). The dried test material was digested in a Tecator Block Digestion 40 System.

Fat was extracted with diethyl ether according to the Soxhlet method.

Ash was determined after incineration at 550°C for 20 hours.

TiO_2 was determined after a method described by Njaa (1961). The titanium concentration was measured at 400 nm in a Zeiss PM Q II spectrophotometer.

Cr_2O_3 was determined by atomic absorption spectrophotometry (Rosenlund and Njaa, 1982) in solutions of sample from the protein digestion.

Consistency of feed samples was determined with the help of a Sur Penetrometer PNR 6 (Sommer and Runge K.G., Berlin). The consistency was characterized by how deep a cone - shaped weight penetrated the feed in a certain time period. The weight was allowed to fall freely for 5 seconds, and the depth measured in tenths of millimeters.

Two types of weights were used:

1) MA-Duralkonus 40° (18-176), 31.5 grams on Ma-Fallstab (18-177), 48.5 grams, for regular moist feed.

2) Plexiglas - Spezialkonus (special cone), 15 grams on MA-Fallstab (18-045), 10 grams, for acid silage feed.

4. EXPERIMENTAL

p.11

The binders used in the project were made available by various firms. Many of the binders came from the firm Keddell and Bommen A/S who distribute various binders from the Hercules company. Various types of alginates were received from Protan and Fagertun A/s. In addition, the firms Dow Chemical (Norway) A/S, Steen Wallin Company A/S, Vaksdal Mølle (Mill) A/S, Mowi A/S and Paus and Paus A/S have been very cooperative and sent products they felt could be suitable as binders in moist feed for fish.

Some concepts and expressions used in the text are described in the following paragraph:

Binder mixture was a pre-mixture of binder and cellulose powder. The mixture contained 0-40% binder.

Base feed was ground up from 60% capelin and 40% pollock.

Moist feed was base feed with 5% binder mixture and sometimes 2% vitamin mixture added. (Table 21).

Acid silage feed was base feed preserved with 2.5% formic acid and 0.5% propionic acid. The silage had a pH of ca. 3.8.

The biological trials with rainbow trout as the experimental animal were carried out at the aquacultural stations in Matre and Austevoll. The daily experimental work was performed by agronomist Jan Erik Fosseidengen.

4.1. Consistency measurements

Sample mixtures of base feed for penetrometric measurements (consistency, texture measurements) were ground in a meat grinder (Hobart,perforated plate with holes of 4.5 mm diameter)

p.12

In order to get a homogeneous mixing in the feeds, the binders were first diluted with cellulose powder. The moist feed, 95% pollock/capelin mass and 5% binder mix , was mixed in a kitchen mixer for 3 minutes before being distributed in a sufficient number of sample cups for the trials.

The concentration of binder in the feed was from 0.5 to 2.0 percent of the total weight, and as control feed containing 5% pure cellulose powder was used.

4.1.1. Preliminary experiments

The availability of binders at the start of the project was relatively limited so the first series of experiments were carried out with about ten different products.

To investigate if the binding ability in the moist feeds changed with time, the consistencies were measured at various times after addition of binders. The penetrometric measurements were done after 4 hours at 24°C and after a total of 22 hours, respectively 18 hours at 4°C and 4 hours at 24°C.

The results are given in Table 1, and the values are shown in relation to the consistency in control feeds without binder. Products that had a firm texture have the lowest penetration values.

Most binders had a positive effect on the consistency of the moist feed both after 4 hours and after 2 hours. A small increase in the binding ability between the first and the second measurement was also noted for almost all these products. Feed with the binder CMC had a considerably softer consistency than the control feed.

The project also included an evaluation of the effects of the binders in the preparation and feeding of the moist feeds to rainbow trout.

Binder concentrations from 0.5 to 2.0 % were used. A part of each feed mixture were left at room temperature overnight and the rest was fed to rainbow trout 1-2 hours after preparation.

The experiences from these trials are shown in Table 2. Feed p.13
without binder had a relatively good consistency to work with, but it dissolved easily in water and therefore resulted in high feed wastage.

The CMC type used did not improve the feed consistency and did not lead to any reduction in feed waste.

In the use of the other binders the feed waste was reduced considerably, but the effect on feed consistency varied with the product and amount added.

Concentrations of 1-2 % Methocel K_{15} M prem. gave a sticky

feed that was difficult to work with. Addition of 1% Methocel K_4M prem. which is a quality with lower gel strength did, however, result in an elastic and good consistency in the moist feed.

4.1.2. Penetrometric measurements of moist feed, comparisons of 30 different binders.

The project did eventually receive a considerable number of binders that the suppliers felt could be suitable as consistency improvers in moist feeds for fish.

Among the 30 different products the main types of binders (CMC., guar gum and alginate) were represented, but there were also a number of other cellulose derivatives, soy concentrate and mixtures that contained i.a. guar gum. (Of the latter types can be mentioned the products K.59.5, ADX-72, SG-1021 and RG-1031, see Table 4).

Since it was impossible to carry out biological trials for all these products within the scope of the project, penetrometric measurements were carried out to find the binders within each product group that had the best effect on the consistency of moist feeds.

To have a standardized base feed for the whole series of experiments, a larger quantity of pollock and capelin was ground up and frozen in estimated daily rations. The composition of the base feed is shown in Table 3.

A total of 0.5 mg of 1.0% binder was added to the moist feeds, and the consistency was measured penetrometrically at 18 C. In all binder mixtures where alginate was included as a binder, except for acid silage feeds, a CaHPO - supplement of 15% of the amount of alginate was added. p.14

Each feed mixture was distributed in 12 parallel sample cups. The consistencies in four of them were measured just after preparation of the feed. The next four were measured after standing for 4 hours (2 hours at 4 C + 2 hours at 20 C), and the rest were stored for 24 hours (22 hours at 4 C + 2 hours at 20 C). The results of the test series are given in Table 4.

In the penetrometric measurements it was found that the consistency of the control feed was unchanged after 24 hours storage.

Shortly after preparation of the moist feeds it was found that the binders had little effect, and in very many samples the consistency was softer than in the control feed (rel. values >100).

After 4 and 24 hours very few of the binders had given the feeds a substantially firmer consistency.

Variations in the binding ability were large between different qualities of the same product as well as between main types of binders.

Of the three alginates tried, the product EFN increased the firmness in the product most. The pure guar gum products exhibited varying qualities. Three of them had a weak consistency improvement effect, and this effect seemed to increase with the time after preparation. Of the various cellulose derivatives tested, the results were poorest for the carboxy-methyl-cellulose (CMC) type. All CMC- products, except CMC-Celcol and CMC $7H_4$, resulted in moist feeds with , in some cases, much softer consistency than the control feed. Other cellulose derivatives tried were Methocel (hydroxypropylcellulose) and Natrosol (ethylhydroxyethylcellulose), and these products, together with Legacon N Cesalpinia (guar gum type), had the greatest positive effect on the feed consistency.

The soy concentrate Newpro had a small positive effect on the consistency, while the products Biozan R, RG-1031 and SG-1021 all lowered the viscosity in the moist feed.

4.1.3. Different binder combinations for moist feeds. p.15

A series of penetrometric measurements were carried out on moist feeds to see if the binding ability could be improved by combining different types of binders.

Different guar gum qualities and the cellulose derivative Methocel $K_{15}M$ prem. were mixed in a 1:1 ratio with respectively

the carboxymethyl cellulose Blanose 7H and the alginate Protatek EFN.

The consistency in the test feeds were measured 2 hours after preparation and related to the values in control feeds. The temperature was 13°C, and 1% binder in the feed was used.

It can be seen from the results in Table 5 that little is achieved with respect to feed consistency by mixing various types of binders. The combinations gave firmer feed than alginate and CMC alone, but the greatest effect was found by adding 1% of the products Legacon N and ADX-72.

It was shown earlier (see 4.1.2.) that the combination Natrosol 250 HR- Blanose 7L had poorer binding ability than the best component (Natrosol) had alone.

4.1.4. Binders for acid silage feeds.

The project "Binders in moist feed for fish" has been coordinated with the project "Fish silage for farmed fish".
In order to use silage as the main component in feeds for farmed fish, an effective thickener must be added.

The project was aimed at finding binders that were active in feeds with a low pH since the characteristics of the products are usually affected by the acidity.

The effect of the various products received in an acid environment were compared in a series of penetrometric measurements.

The test feed consisted of 95% acid silage, 1% binders and 4% fish meal. The fish meal acts as a carrier for the binder, and had the same function as cellulose powder in earlier trials with moist feeds. In the control feed the binder was replaced with fish meal so that this feed contained a total of 5% fish meal. p.16

The consistency of the feed was measured just after preparation, after 1 and after 24 hours standing at 18°C.
A lighter weight was used for these penetrometric measurements since the consistency in the fish silage was almost liquid.

Table 6 gives the results of the penetrometric measurements.

The trials showed that the various qualities of CMC were not very suitable for use in an acidic environment. The best feed consistency in this group was achieved with the product 7HOF.

The binders that best improved the consistency were the products RG-1031, SG-1021, Biozan R (Xanthan - gum) and the guar gum qualities ADX-72, Supercol U and CSSA. The three first were recommended by the manufacturer for use at low pH. The same applies to Protanal AG-66 and Blanose 7HOF, but the binding abilities for these were clearly poorer than for the above mentioned products at pH 3.8.

The binder Soy Concentrate Newpro did not improve the consistency of fish silage, while the products Methocel, Natrosol and Legacon N had a medium binding ability at low pH.

The trials showed that the reaction times of the various binders are different. In order to achieve the full effect of the binders, the feed should sit for at least an hour after preparation.

4.1.5. Binders for feeds consisting of 50% moist feed and 50% acid silage feed.

Addition of 1% binders and 4% fish meal (see 4.1.4.) did not give an acceptable consistency to the fish silage. At the same time the experiments under the project "Fish Silage for Farmed Fish" demonstrated that rainbow trout do not grow well on 100% acid fish silage feed. However, the growth in the groups that received a mixture of 50% silage and 50% moist feed was just as good as in the control groups that received 100% moist feed. p.17

A series of consistency measurements were carried out on feeds consisting of 50% acid silage feed and 50% moist feed. The final feed mix had a pH of ca.4.6. As binders were chosen the products that exhibited the greatest ability to improve the consistency in pure fish silage. The binder was mixed with fish meal so that the concentrations of binder and fish meal in the test feed were respectively 1 and 4%. The control feed contained 5% fish meal.

The consistency in the samples was measured just after preparation and after standing for 2 and 20 hours at 17°C.

The results are given in Table 7. The absolutely best binders for this feed mixture were the products RG-1031, SG-1021 and Biozan R. The feed mixtures with these binders had an elastic and firm consistency.

Of the remaining binders that were tried, the guar gum qualities had a somewhat better effect than the alginate Protanal AG-66 and the cellulose derivatives Natrosol, Methocel and Blanose.

4.2. Biological trials

4.2.1. Digestibility trials with TiO_2 as indicator.

The addition of binders to moist feed for fish could possibly affect the uptake of nutrients from the intestine. In order to study this effect, a digestibility trial was carried out at the Aquaculture Station at Matre.

The trial consisted of 21 groups of rainbow trout, 10 fish in each group with an average weight of ca. 200 grams. A total of 19 groups were given feeds containing from 0.5 to 2.0% of 8 different binders for 14 days. Two control groups received feed without addition of binder. The chemical composition of the moist feed is shown in Table 8.

p.18

To determine apparent digestibility of protein and fat, 0.2% titanium dioxide (TiO_2) was added as an inert marker to the feeds.

At the end of the feeding period, the gastro intestinal system from each fish was tied off in 5 segments and frozen. Figure 5 shows how the digestive system of the trout was divided into stomach (S_1), pyloric caeca (S_2), and three sections of the intestine of equal length (S_3, S_4, S_5).

For the chemical analyses, collective samples for each of the 5 stomach and intestine segments were prepared. The samples were freeze dried and analyzed for protein, fat, ash and titanium

oxide.

In the use of inert markers, it is expected that the concentration of the indicator will increase towards the end of the intestine as the nutrients are being absorbed.

The analytical results for titanium oxide gave the highest value in the stomach of the fish. It was therefore not possible to calculate apparent digestibility of protein and fat in this experiment. Tables 9-11 show the values found for contents of protein, fat and ash in dry matter from the stomach and intestine segments.

As shown in tables 9 and 11, there were not found clear differences between the binder groups and control groups with respect to contents of protein and ash in the dry matter.
Compared with the control groups, most of the groups that had binders added to the feed had a higher fat content in the last part of the intestine (Table 10). The analytical method used for fat determines the amount of triglyceride, usually called available fat in the sample.The high fat content in S in some of the groups can indicate that some of the binders have an inhibiting effect on fat absorption.

4.2.2. Digestibility trials with Cr_2O_3 as indicator.

The results from the digestibility trials with TiO_2 as a marker indicated that there was a possible inhibiting effect of some binders on the digestibility of fat in the feed. It was therefore necessary to carry out a new digestibility experiment with another indicator. We then chose chromium sesquic oxide (Cr_2O_3) as the inert indicator. This substance is well suited for digestibility studies in fish (Austreng, 1978; Lied o.a., 1982). It has also been recently found here at the Vitamin Institute (now Institute of Nutrition) that Cr_2O_3 and protein can, as with TiO_2 and protein, be determined in the same solution.(Tønnessen, 1979)

p.19

This digestibility experiment was carried out at the aquacultural station in Austevoll.

The experiment consisted of 20 groups with 15 rainbow trout in each with an average weight of ca. 300 grams. Eighteen groups were given moist feed with various binders added, while the feed for the control group had no additives. All moist feed mixtures contained 1gram $Cr_2 O_3$ per kilo moist feed, and the chemical composition is given in Table 12.

The binders for the trials were chosen on the basis of results from penetrometric measurements (Section 4.1.2.).

The fish were fed ad libitum for at least 6 days with the test diet before samples were taken. The stomach and intestine digestive systems were taken out and divided into 5 segments (Fig. 5). The contents in each segment were flushed out with physiological saline solution and freeze dried individually. For chemical determination of protein, fat, ash and chromium, the samples in each group were pooled due to the analytical capacity of the laboratory.

There were large variations found in the filling of the digestive system within each group. Some fish were almost empty, and to get a representative pooled sample from each segment within the groups, an equal amount of dry matter was taken from at least 5 fish for each segment test.

In the preparation and feeding of the moist feeds, a subjective evaluation of the effect of the binders on consistency and feed waste were made.

Apparent digestibility (TF) was determined as : p.20

$$TF = 100 - \frac{\%\text{ nutrient in segm.x }\%\text{ chrom. in feed}}{\%\text{ nutrient in feed x }\%\text{ chrom. in segment}} \quad \% = 100\% - TG$$

The values for TG (apparent recovery of nutrients) are determined directly from the analytical results. In Tables 13 and 14 the results from the digestibility trials are therefore given as apparent recovery of the protein and fat in the moist feeds in the various digestive system segments. The values for ash are given as g/kg dry matter in Table 15.

The results from the subjective evaluation of the effect of

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the binders on the consistency of the moist feeds and their ability to reduce feed waste are given in Table 16.

Comparison of the various feed mixtures shows that the binders had different effects on the consistency and feeding properties of the moist feeds. (Table 16). Addition of certain products like Methocel, Blanose 7L and Natrosol 250 HR, gave sticky feed mixtures. Most of the feed mixtures that had guar gum added had an elastic and good consistency.

Addition of binders resulted in more "coherent" feeds than the control feeds. This resulted in less feed waste when fed to trout. The differences between binders were considerable as shown in Table 16. The best effect had the guar gum products Methocel F_4 M prem. and the alginate Protatek EFN. The least effect was found with the soy concentrate Newpro.

Tables 13 and 14 show that the apparent digestibility of protein and fat in the control groups were respectively 80 and 97 % on the average.

Addition of binders of the types CMC, alginate and soy concentrate seemed to have little effect on the uptake of protein an fat from the intestine. In general the guar gum samples seemed to have the most retarding effect. In some groups that received binders of the last type, apparent digestibilities were between 50 -60 %. A correspondingly low digestibility was also found in groups where the feed had various Methocel- and Natrasol qualities added. p.21

The highest apparent recovery of fat was found in the K.59.5 group (guar gum type). The amount of fat in the last segment of the intestine was about 10 times higher than in the control group; i.e. apparent digestibility of fat was only 66%. Also other guar gum types and some qualities of Methocel and Natrosol led to a considerable reduction in apparent fat digestibility, values between 73 and 85%.

The results from the determination of ash contents (Table 15) showed no appreciable differences between the binder groups and the control groups.

The results from the subjective evaluation of feed properties (Table 16) were compared with the analytical results (tables 13-14). It appears as if the binders that have the most favorable effects on feed consistency and feed waste also retard the absorption of proteins and fat more than the others. This applies to all guar gum qualities, Natrosol and Methocel, but not for Blanose $7H_4$ (CMC) and the alginate EFN.

4.2.3. Growth trials.

To get a total evaluation of the connection between the ability of the binders to reduce feed waste and their influence on uptake of nutrients in the intestine, it was necessary to carry out feeding trials over a longer period.

A feeding trial with rainbow trout was carried out at the Aquacultural Station in Austevoll. The fish were held in round glass fibre tanks (volume 1.7 cu.m.) The water temperature dropped gradually from 11° to 7° C in the 3 month long trial period. The salinity was between 32 and 34 0/00.

The trials consisted of 10 groups with 60 fish in each which weighed on an average ca. 85 grams at the beginning of the trials. For nine of the groups various binders were added to the moist feed with the tenth as the control group. The fish were hand fed according to appetite 3 times a day in the first half of the trial period. The rest of the time twice daily due to shorter length of day. p.22

In addition to registration of growth, four fish were randomly taken out of each group at the end of the trials for analyses of dry matter, protein, fat and ash. Corresponding analyses were carried out on four fish at the beginning of the trials. The moist feeds were also analyzed.

A subjective evaluation of feed waste in the various groups was carried out at the end of the trials.

Table 17 shows the composition of the moist feeds used. Mixture 1 was used the first 8 weeks and mixture 2 the last 4 weeks of the trial.

The analyses show that mixture 2 had a substantially lower content of dry matter than mixture 1. This also resulted in higher feed waste in the last part of the trial period.

The results from the growth trials are shown in Table 18.

The mortality during the trials was very low except in group 8. The reason for a loss of close to 12% in this group is due to an attack of vibriosis in the first month of the trial. The disease was stopped with the help of feeding with medicines (oxytetracycline), but the fish in this group were weakened considerably and not feeding very actively in most of the trial period. This means that the results from group 8 are somewhat uncertain.

The lowest growth (105 grams per fish) was found in the control group. Best growth (125 grams per fish) were found in the groups where the binders ADX-72 and Methocel K4M prem. were added to the feed. The growth was also good (122 grams per fish) for the group with Guar gum CSSA.

The growth trials should have been repeated, but several planned trials were not successful due to vibriosis or attacks by cold water bacteria.

The results from the subjective evaluation of feed waste are shown in Table 19. The ability of the binders to reduce feed waste varies considerably. In the groups that were given Natrosol and Blanose 7H the feed waste was about the same as in the control group, and table 18 shows that the feed factors (grams feed/ grams weight gained) in the same groups were high. Lowest feed waste was observed in the use of the binders Methocel K4M prem., Protatek EFN and ADX-72. This resulted in good feed factors for these trial groups. The lowest feed consumption per kilo growth was found in the Methocel group that had a feed factor of 4.2. The feed factors for the groups with guar gum CSSA and Guar gum TH 1 were also low and the feed waste in the use of these binders was relatively low. p.23

Table 20 shows that there were no substantial differences between the groups with respect to dry matter,

protein, fat and ash.

However,in the trial period there was a general increase in the fat content and a corresponding reduction in the protein content.

5. SUMMARY

p.24

The project "Binders in moist feeds for fish" has carried out a number of experiments with the objective of finding suitable binders for moist feeds for farmed fish. Of essential importance for recommending a binder for this purpose is how effective the product is in reducing feed waste.

The effect of the binder on the consistency and feeding properties of the feed is also of great importance. The binder should also not retard the absorption of nutrients to any degree.

The effect of the various types of binders was tested objectively with the help of consistency measurements (penetrometric) and by digestibility and growth trials in rainbow trout. Subjective evaluations were also carried out of the preparation and feeding of moist feeds with various binders added.

The project received a total of 30 different products for evaluation, but they can be grouped in the main types guar gum, cellulose derivatives, alginates and soy concentrates.

In the following the results of the various trials with moist feeds are summarized under each main group of binders.

GUAR GUM

Most products belonged under this main type, some were pure guar gum types and others were mixed products with guar gum as the major component.

The penetrometric measurements (Table 4) showed varying results for this group, and addition of binders did not result in any substantial increase in the firmness of the feed. On the basis of these measurements, five binders were selected for digestibility trials. The results indicate that all these seemed

to retard the absorption of both protein (Table 13) and fat (Tables 10, 14) to varying degrees. Apparent digestibility of protein was reduced by up to 30% (from 80 to 50%) with the addition of binders of this type. Corresponding reduction for fat was also 30% (from 97 to 67%). The poorest result was found for the product K.59.5 and the best result for ADX-72. p.25

The binder K.59.5 was not included in the growth trials. For the other four the results were quite variable (Table 18).
Two of the groups (ADX-72 and Guar gum CSSA) demonstrated very good growth and low feed factors, respectively 4.2 and 4.7.
In Guar gum TH 1 trial group the growth was somewhat lower, but the feed factor was good (4.7). The binder Legacon N was only added at 0.5% in contrast to 1% for the others.This group had poor growth and high feed factor (5.9) which is connected with high feed waste.

Addition of guar gum resulted in elastic and good feed consistency (Tables 2,16). At low additions the moist feeds were somewhat loose, but by increasing the concentrations the binding ability became better. Feed waste with the use of this type binder was very low(Tables 2,16), but due to high water content in the moist feed (Table 12) the feed waste was somewhat higher towards the end of the growth trials (Table 19).

CELLULOSE DERIVATIVES

This group includes carboxymethylcellulose (CMC), ethylhydroxyethylcellulose and hydroxypropylcellulose that exhibited quite different properties. Each sub-group will therefore be presented individually.

Carboxymethylcellulose: In addition to the CMC products, Blanose also belong to this group.

The moist feeds with CMC added usually had a softer consistency than the control feeds as demonstrated by penetrometric measurements. The feeds did not stick together well and the effect of the binders decreased on storage (i.e. standing for one day). CMC did not demonstrate any negative

effects on the uptake of protein and fat (Tables 13-14). Of the various CMC- qualities, Blanose $7H_4$ resulted in the best feeding properties of the moist feed (Tables 2, 16), and only this type was included in the growth trials.

The growth in the CMC- group was relatively poor (Table 18), but this was probably due to an attack of vibriosis in the first trial month. The feed factor (5.2) was average in the trials (Table 18), but feed waste was relatively high. (Table 19). p.26

Ethylhydroxyethylcellulose: Of this type binders the project received several qualities of the product Natrosol. Penetrometrically it was found that these binders had a very good effect on the feeds (Table 4) even with an addition of 0.5%. The product gave the moist feed a firm consistency, but the HR-quality resulted in sticky feed (Table 16). Addition of 1% Natrosol 250 MR seemed to have reduced apparent digestibility of protein and fat (Tables 13-14). The effect was less for the HR-Quality.In the growth trials both the MR- and the HR- qualities were tried with 0.5% addition in the moist feed. The feed factors for the two groups were poor, respectively 5.8 and 5.9 (Table 18). The growth was best in the MR- group (Table 18), and this can have a connection with a higher waste of feed in the HR_ group (Table 19).

Hydroxypropylcellulose: The product Methocel belongs to this subgroup. The product had a weak positive effect on the consistency of moist feeds when measured penetrometrically (Table 4). The effect was dependent on the concentration and quality of the binder, 0.5% addition of K_4 M prem. gave a loose consistency, while 2% of K_{15} M prem. resulted in a feed that was much too firm (Table 8). The various Methocel qualities appeared to lower the absorption of protein and fat to different degrees. (Tables 13-14). Methocel K_4 M prem. was chosen for the growth trials. This group showed the best results both with respect to growth and feed factor Table 18). The feed waste was insignificant. (Table 19).

ALGIN

Three different types of algin were tested in penetrometric trials (Table 4). The consistency in the feed became firmer than the control feed with addition of 1% alginate, but the binding effect was not very high.

Alginate gave the moist feed a firm consistency that was not affected by variations in the concentration of binders between 0.5 - 2.0 % (Table 2). p.27

The best result was achieved with the product Protatek EFN which on this basis was chosen for further trials. The digestibility trial showed that Protatek EFN did not have any negative effect on the uptake of protein and fat from the intestine (Tables 13-14).

Growth trials showed relatively good growth and feed factor for the alginate group (Table 18). Use of alginate also led to a considerable reduction in feed waste (Tables 16,19).

SOY CONCENTRATE

A product of this type, Soy Concentrate Newpro was tested. This binder appeared to be poorly suited for use in moist feeds for fish. Improvements in consistency were low, both measured penetrometrically and subjectively (Table 4). The product did not reduce apparent digestibility of protein and fat (Tables 13-14).

Since addition of this binder did not lead to substantial reduction in feed waste (Table 16) it was excluded from the growth trials.

Combinations of various types of binders were also tried , and the effect in moist feeds were measured penetrometrically. The combinations gave the feed a consistency that was intermediate to that obtained by the components individually. (Table 5).

Even if a moist feed with 5% addition of binder shows a low value penetrometrically (Legacon N, Natrosol), it appears as if 1% addition is necessary to reduce feed waste sufficiently.

Penetrometric measurements only indicates the firmness of

the feed, but the method does not show how well the feed hangs together.

In these trials a subjective measure for feed waste in feeding trials with fish was also given.

For the solubility of the feeds in water a laboratory method could possibly have given more definite and reproducible results.

Feeds with good properties showed in digestibility trials most often the greatest retardation of protein and fat. This did not apply to the alginate Protatek EFN.

Growth trials showed, however, that good feed properties that resulted in reduced feed waste more than compensated for the reduced digestibility of protein and fat (Table 18). Guar gum CSSA, ADX-72 and Methocel K_4M prem. all exhibited good feed properties and poor protein- and fat digestibilities, but gave the best growth and feed utilization in the trials.

The project was coordinated with the project "Fish silage for farmed fish".

Binders that were active in an acid medium (pH 3.8) were chosen through penetrometric measurements (Table 6). The products that gave the best consistency in these tests were then tried in a more realistic feed that consisted of 50% silage and 50% non-preserved feed. (Table 7).

The most effective binders were RG 1031, SG 1021 and Biozan R. These products clearly stood out by giving the feeds a good consistency and were also recommended for low pH values by the manufacturer. The Guar gum products ADX-72, Legacon N, Guar gum TH 1, Supercol U and CSSA took an intermediate position.

6. CONCLUSION.

p.29

Wet feeds that had commercial binders added chiefly from the three groups guar gum, cellulose derivatives and algin, were studied for feeding properties, digestibility and growth in rainbow trout.

Penetrometric measurements together with subjective evaluations of feed waste during feeding have in some cases shown

large differences in moist feeds with different types and amounts of binders.

Use of Guar gum generally resulted in the best feed properties. Alginates also demonstrated good improvements in feed consistency. Some cellulose derivatives, especially the hydroxy-propylcellulose Methosel K M prem. also had a favorable influence on feed structure. The trials showed that it was necessary to add 1% binder to moist feeds.

The project also found good binders for acid silage feeds.

Digestibility trials showed substantial differences in reduced protein- and fat digestibilities from the use of binders. The digestibilities were poorest in rainbow trout that had received moist feeds with the best feeding properties.

The growth trials with rainbow trout showed, however, that groups that received feeds with good feeding properties (good consistency, insignificant feed waste) had the highest growth rates and the best feed utilization.

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I tillegg kommer informative kataloger og brosjyrer fra:

Dow Chemical (Norway) A/S
Keddell & Bommen A/S
Protan & Fagertun A/S.

Further, informative catalogs and brochures from :

Literature

Tønnessen, W. (1979). External and internal indicators in protein digestibility trials of Gadoids. Thesis in nutritional biology , University of Bergen.

In addition, informative catalogs and brochures were received from:

Dow Chemical (Norway) A/S
Keddell & Bommen A/S
Protan & Fagertun A/S

PART II. TABLES AND FIGURES

Table 1. PENETRATION TRIALS WITH MOIST FEEDS AFTER ADDITION OF VARIOUS BINDERS

The values, that are averages of at least 4 measurements, are relative to the consistency in control feeds without binder. The variation coefficients in parentheses.

Binder	Amount added	Consistency measurement of the feed after 4 hrs at 24°C	Consistency measurement of the feed after 18 hrs. at 4°C + 4 hrs. at 24°C
Kontrollfôr	-	100 (6.1)	100 (3.4)
Guar gum CSSA [1]	0.5	89.8 (5.3)	86.2 (4.9)
Guar gum CSSA [1]	1.0	90.3 (2.0)	89.2 (1.9)
Methocel K_4Mprem [2]	1.0	97.9 (1.3)	88.7 (4.9)
Methocel K_{15}Mprem [2]	1.0	93.4 (2.7)	94.4 (1.6)
Methocel K_{100}Mprem [2]	1.0	104.1 (5.3)	91.3 (4.8)
Guar gum TH 1 [3]	0.5	96.9 (5.9)	88.7 (1.6)
Guar gum Cesalpinia [3]	0.5	96.4 (5.6)	82.1 (2.9)
Guar gum Cesalpinia [3]	1.0	93.9 (4.3)	85.6 (2.6)
ADX-72 [3]	1.0	91.8 (1.9)	90.3 (3.0)
CMC [3]	1.0	114.8 (3.6)	119.5 (7.1)
Natrosol 250 LR [3]	1.0	92.3 (6.0)	87.2 (0.9)

The binders were made available by:

1 - Mowi A/S

2 - Dow Chemical (Norway) A/S

3 - Keddell & Bommen A/S

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Table 2. BINDERS, VARIOUS CONCENTRATIONS ADDED, EXPERIENCES IN PREPARATION AND FEEDING OF MOIST FEEDS TO RAINBOW TROUT.

Binder	Amount added %	Experiences from preparing and feeding moist feeds.	Experiences from use of the moist feeds.
Control feed	-	Relatively firm and "dry" consistency	Large feed waste, dissolves in water
Guar gum, CSSA	0.5	Good consistency, a little loose	Little feed waste
	1.0	Good consistency	" " "
	2.0	" "	" " "
Guar gum TH1	0.5	A little loose consistency	Some feed waste
	1.0	Good consistency	Little feed waste
Natrosol 250 LR	1.0	Good consistency	Little feed waste
CMC, Celcol*	0.5	Loose consistency, effect decreasing on storage	Large feed waste
	1.0	" " " " " "	" " "
	2.0	" " " " " "	" " "
Methocel K_4Mprem	0.5	Consistency a little too loose	Some feed waste
	1.0	Fine consistency	Little feed waste
Methocel K_{15}Mprem	0.5	Fair consistency	Some feed waste
	1.0	" " , difficult to pellet	Little " "
	2.0	Fair binding effect, " " " ere	No " "
ADX-72	0.5	A little soft consistency	Little feed waste
	1.0	Firm consistency	No " "
Alginat H-120	0.5	Firm consistency	Little feed waste
	1.0	" "	" " "
	2.0	" "	" " "

*Bindemidlet var stillt til rådighet av Vaksdal Mølle A/S.

Table 3. COMPOSITION OF BASE FEED (GROUND POLLOCK AND CAPELIN) FOR PENETROMETRIC MEASUREMENTS

Dry matter g/kg	Of dry matter		
	Protein g/kg	Fat g/kg	Ash g/kg
249	559	271	76

Table 4. PENETROMETRIC MEASUREMENTS, EFFECT OF VARIOUS BINDERS ON THE CONSISTENCY OF MOIST FEEDS.

The values are averages of 4 parallel measurements, and the results are related to the value for consistency in control feed without binder, the numbers in parentheses are variation coefficients for the measurements. The measurements were carried out at 18 C.

Binder	Amount added %	Consistency measurements (hours after preparation of feed)		
Kontroll	-	100	100	100
Natrosol 250 LR [1]	0.5	98.7 (1.6)	103.4 (2.3)	94.6 (5.7)
	1.0	100.4 (6.7)	94.6 (5.0)	91.5 (2.6)
Natrosol 250 MR [1]	0.5	85.2 (6.6)	92.4 (2.4)	83.0 (4.5)
	1.0	83.5 (4.1)	81.7 (0.3)	80.7 (0.7)
Natrosol 250 HR [1]	0.5	100.8 (4.1)	91.9 (2.6)	93.7 (2.9)
	1.0	86.1 (9.5)	78.6 (1.9)	84.3 (1.0)
Blanose CMC 7L [1]	0.5	104.2 (3.7)	108.9 (2.4)	103.1 (4.7)
	1.0	114.8 (1.4)	113.4 (2.9)	108.5 (4.2)
Blanose CMC 7M [1]	0.5	111.3 (3.2)	114.1 (1.4)	104.0 (3.7)
	1.0	120.2 (2.6)	116.5 (3.1)	118.4 (3.0)
Blanose CMC 7H [1]	0.5	117.3 (2.8)	112.9 (3.8)	108.9 (5.9)
	1.0	112.2 (2.3)	121.0 (5.4)	125.6 (5.3)
Blanose Cellulose Gum 7HOF [1]	0.5	108.9 (4.1)	109.3 (3.7)	108.1 (2.3)
	1.0	109.7 (1.1)	119.1 (2.7)	117.9 (1.7)
Refined CMC 7H [1]	0.5	113.5 (3.9)	112.9 (3.3)	108.9 (3.1)
	1.0	109.3 (4.1)	120.5 (2.1)	124.2 (2.3)
Produkt K.59.5 [1]	0.5	105.1 (2.2)	114.7 (0.9)	116.1 (1.3)
	1.0	97.0 (1.8)	96.4 (3.1)	118.8 (1.6)
ADX-72 [1]	0.5	108.4 (2.3)	114.7 (2.3)	118.8 (1.1)
	1.0	99.6 (2.1)	102.7 (1.7)	118.3 (2.2)
Natrosol 250HR og Blanose CMC 7L (1:1) [1]	0.5	93.2 (4.2)	103.1 (0.7)	86.9 (4.4)
	1.0	96.2 (3.2)	102.2 (1.3)	93.7 (0.6)
CMC-Celcol [2]	0.5	110.3 (0.9)	104.7 (1.1)	93.8 (2.2)
	1.0	105.6 (4.9)	99.5 (0.4)	104.7 (5.3)
CMC $7H_4$ [1]	0.5	107.5 (4.5)	99.1 (1.2)	97.6 (1.2)
	1.0	98.5 (2.8)	95.2 (3.4)	100.4 (3.2)
Biozan R [1]	0.5	130.5 (1.7)	113.3 (5.4)	119.5 (1.3)
	1.0	130.9 (3.2)	122.8 (3.6)	120.4 (3.0)

Fortsettelse av tabell 4.

BINDEMIDDEL	(%)	<0.5	4	24
RG 1031 [1]	0.5	110.3 (4.3)	98.5 (5.0)	101.4 (6.1)
	1.0	113.1 (4.7)	104.7 (6.1)	108.1 (1.9)
SG 1021 [1]	0.5	114.5 (4.8)	110.9 (4.0)	105.7 (2.0)
	1.0	118.3 (2.6)	119.9 (2.4)	114.7 (2.9)
Soyakonsentrat Newpro [3]	0.5	104.6 (3.8)	96.6 (4.2)	91.4 (0.0)
	1.0	118.3 (4.2)	106.6 (1.1)	94.2 (1.2)
Alginat B 120 [4]	0.5	117.8 (2.2)	102.8 (4.2)	103.3 (3.3)
	1.0	106.1 (3.5)	104.2 (3.5)	99.0 (4.7)
Protatek EFN [4]	0.5	108.9 (3.3)	101.8 (1.0)	89.5 (2.5)
	1.0	106.1 (5.9)	93.8 (3.1)	90.9 (3.0)
Protanal-CN [4]	0.5	107.5 (3.4)	103.8 (1.0)	95.2 (4.3)
	1.0	110.3 (3.2)	99.5 (7.1)	99.0 (1.4)
Guar gum Supercol U [5]	0.5	117.3 (2.9)	115.6 (2.8)	110.9 (1.6)
	1.0	100.9 (3.5)	109.4 (2.2)	110.0 (3.6)
Guar gum U/Powder [5]	0.5	113.1 (1.0)	113.3 (1.4)	105.2 (2.3)
	1.0	105.1 (3.8)	96.6 (4.8)	105.7 (1.6)
Guar gum CSSA [6]	0.5	112.6 (2.9)	102.8 (5.8)	97.1 (4.2)
	1.0	100.0 (6.4)	92.8 (4.1)	100.9 (4.6)
Guar gum TH1 [1]	0.5	101.8 (2.9)	97.1 (4.7)	95.2 (4.3)
	1.0	95.7 (6.3)	98.1 (3.1)	100.9 (1.4)
Guar gum Cesalpinia [1]	0.5	115.9 (2.5)	107.1 (3.1)	96.7 (4.2)
	1.0	116.9 (2.8)	108.5 (2.1)	96.7 (1.9)
Legacon N Cesalpinia [3]	0.5	106.1 (3.6)	93.8 (5.8)	86.7 (6.1)
	1.0	103.2 (1.6)	92.8 (2.8)	90.0 (1.3)
Methocel K_4M prem. [7]	0.5	93.8 (2.5)	96.2 (2.6)	82.4 (3.6)
	1.0	97.2 (3.4)	96.2 (1.5)	92.3 (4.1)
Methocel $K_{15}M$ prem. [7]	0.5	101.9 (4.5)	103.3 (0.7)	91.9 (1.8)
	1.0	100.9 (2.1)	99.5 (0.2)	86.7 (2.9)
Methocel $K_{100}M$ prem. [7]	0.5	104.7 (4.4)	102.3 (2.6)	86.7 (6.4)
	1.0	107.9 (6.9)	105.6 (2.8)	102.4 (1.4)
Methocel E_4M prem. [7]	0.5	103.7 (2.9)	97.6 (3.6)	86.7 (1.7)
	1.0	108.9 (2.2)	93.8 (6.6)	99.0 (2.4)
Methocel F_4M prem. [7]	0.5	106.1 (5.6)	95.2 (1.2)	94.2 (0.7)
	1.0	105.1 (3.5)	100.0 (0.4)	94.3 (5.1)

Bindemidlene var stillt til rådighet av:

1 - Keddel & Bommen A/S
2 - Vaksdal Mølle A/S
3 - Steen Wallin Co. A.S.
4 - Protan & Fagertun A/S
5 - Paus & Paus A/S
6 - Mowi A/S
7 - Dow Chemical (Norway) A/S

Table 5. COMBINATIONS OF VARIOUS TYPES OF BINDERS FOR MOIST FEEDS

The measurements were carried out at 13 C

BINDER	Consistency 1) in the feed 2 hrs. after preparation
Kontroll	100
Protatek EFN	93.1
Blanose $7H_4$	99.8
Guar gum TH1	85.5
Guar gum CSSA	84.6
Legacon N	77.7
Methocel $K_{15}M$ prem.	96.2
ADX-72	77.4
Protatek EFN mixed with	
a) Legacon N	90.0
b) Guar gum TH1	84.3
c) Methocel $K_{15}M$ prem.	93.8
d) ADX-72	81.7
e) Guar gum CSSA	89.1
Blanose $7H_4$ mixed with	
a) Legacon N	93.8
b) Guar gum TH1	90.3
c) Methocel $K_{15}M$ prem.	91.9
d) ADX-72	85.0
c) Guar gum CSSA	91.9

1) The penetration values are relative to the values for consistency in moist feed, and 1% binder was added.

Table 6. PENETROMETRIC MEASUREMENTS OF FISH SILAGE 1)

The results are given as relative values 2)
Measurements done at 18° C.

Binder		Consistency measurement (hours after preparation)		
		<0.5	1	24
Kontroll		100	100	100
Methocel	$K_{15}M$ prem.	98.2	91.3	89.5
	$K_{100}M$ "	100	98.8	96.8
	K_4M "	98.8	94.2	92.7
	E_4M "	100	96.2	95.1
	F_4M "	98.8	97.8	94.5
Natrosol	250 LR	100	98.5	98.8
	250 MR	99.7	93.0	89.9
	250 HR	100	83.4	86.3
Blanose	7 L	99.4	99.1	97.4
(CMC)	7 M	98.8	95.3	95.1
	7 H	95.0	88.4	89.1
	7 HOF	94.2	85.6	89.0
	$7\ H_4$	97.4	99.1	97.7
Guar Gum	Supercol U	95.0	81.1	78.5
	Cesalpinia	97.4	90.4	80.8
	TH1	96.2	82.6	90.7
	CSSA	98.2	84.3	81.4
CMC - Celcol		100	98.5	96.2
Legacon N		100	90.7	83.2
Protanal AG-66 3)		99.1	90.1	87.5
Soyakonsentrat Newpro		99.7	99.1	98.3
ADX-72		96.6	81.6	78.5
RG-1031		95.3	81.4	74.7
SG-1021		98.8	82.3	75.3
Biozan-R		98.5	85.2	78.5

1) Binder addition of 1%

2) Consistency in control feed was unchanged in the trial period

3) The binder was made available by Protan Fagertun A/S

Table 7. PENETROMETRIC MEASUREMENTS, BINDERS FOR MOIST FEED CONSISTING OF 50% FISH SILAGE AND 50% NON-PRESERVED MOIST FEED.

The results are relative to the values in control feed without addition of binder. 1)
Measurements done at 17 C.

Binder	Consistency measurements (hours after preparation)		
	<0.5	2	20
Kontroll	100	100	100
Natrosol 250 HR	105.9	87.9	81.6
Methocel $K_{15}M$	93.4	83.1	77.9
Guar gum Supercol U	82.0	74.2	75.9
Guar gum CSSA	88.9	77.3	76.5
Guar gum TH1	81.3	75.0	73.0
ADX-72	82.5	74.8	74.5
Legacon N	87.3	80.4	76.3
RG-1031	81.1	69.6	63.9
SG-1021	77.3	65.8	60.4
Biozan R	89.5	71.2	53.8
Blanose 7HOF	85.0	80.8	86.9
Protanal AG-66	88.6	80.2	79.7

1) Forsøksfôrene inneholdt 1% bindemiddel.

1) Test feeds contained 1% binder.

Table 8. COMPOSITION OF MOIST FEEDS 1) FOR DIGESTIBILITY TRIALS WITH RAINBOW TROUT. 2)

Dry matter	Of dry matter		
	Protein, g/kg	Fat, g/kg	Ash, g/kg
296	447	209	77

1) The feed contained 20 g. vitamin mixture/ kg (composition of the vitamin mixture is given in Table 21)

2) Titanium dioxide used as indicator.

Table 9. THE PROTEIN CONTENT IN FIVE SEGMENTS OF THE GASTRO-INTESTINAL TRACT OF RAINBOW TROUT FED WITH VARIOUS BINDERS IN THE MOIST FEED.

BINDER	Amount added (%)	Stomach S_1	Pyloric S_2	Intestine S_3	S_4	S_5
Kontroll A	-	440	478	-	511	449
Alginat H 120	0.5	508	488	394	403	517
	1.0	469	408	336	319	359
	2.0	440	538	425	442	368
Guar gum TH 1	0.5	448	433	441	487	397
	1.0	435	415	442	518	482
Natrosol 250 LR	1.0	458	471	413	454	469
ADX-72	0.5	439	541	480	485	438
	2.0	472	430	492	538	538
CMC-Celcol	0.5	416	-	-	537	415
	1.0	447	514	-	565	452
	2.0	458	520	462	485	471
Methocel K_4M prem.	0.5	430	500	438	499	448
	1.0	436	506	415	462	471
Methocel $K_{15}M$ prem.	0.5	470	489	446	468	435
	1.0	471	448	420	440	473
	2.0	467	456	394	448	466
Guar gum CSSA	0.5	449	400	355	496	346
	1.0	432	424	445	495	455
	2.0	468	373	448	517	322
Kontroll B	-	462	542	508	475	444

Ta Table 10. THE FAT CONTENT IN FIVE SEGMENTS OF GASTRO INTESTINAL TRACT IN RAINBOW TROUT FED WITH VARIOUS BINDERS IN THE MOIST FEED.

The fat content is given as g/kg dry matter

Binder	Amount added %	Stomach	Pyloric	Intestine		
	(%)	S_1	S_2	S_3	S_4	S_5
Kontroll A	-	218	245	-	166	82
Alginat H 120	0.5	284	150	261	205	116
	1.0	281	132	243	171	107
	2.0	269	153	183	176	74
Guar gum TH 1	0.5	201	268	231	152	127
	1.0	213	326	228	144	143
Natrosol 250 LR	1.0	213	263	277	227	120
ADX-72	0.5	219	192	193	152	222
	2.0	201	305	155	143	94
CMC-Celcol	0.5	228	-	-	215	92
	1.0	201	204	-	164	66
	2.0	212	200	203	169	69
Methocel K_4M prem.	0.5	219	232	231	187	111
	1.0	213	161	203	145	93
Methocel $K_{15}M$ prem.	0.5	213	183	192	176	102
	1.0	209	264	260	187	149
	2.0	204	268	222	211	141
Guar gum CSSA	0.5	205	309	293	136	124
	1.0	211	319	195	164	105
	2.0	209	388	253	219	405
Kontroll B	-	213	176	144	132	94

Ta

Table 11. THE ASH CONTENT IN FIVE SEGMENTS OF THE GASTRO-INTESTINAL TRACT OF RAINBOW TROUT FED WITH VARIOUS BINDERS ADDED TO THE FEED.

The ash content is given as g/kg dry matter.

Binder	Amt. added %	Stomach		Pyloric	Intestine	
	(%)	S_1	S_2	S_3	S_4	S_5
Kontroll A	-	108	72	-	94	172
Alginat H 120	0.5	84	104	101	125	115
	1.0	117	151	155	184	192
	2.0	96	79	98	97	196
Guar gum TH 1	0.5	101	69	88	93	140
	1.0	111	76	104	106	125
Natrosol 250 LR	1.0	112	73	86	91	116
ADX-72	0.5	129	73	90	95	98
	2.0	92	81	125	131	129
CMC-Celcol	0.5	120	-	-	83	162
	1.0	133	74	-	88	176
	2.0	113	73	85	101	165
Methocel K_4M prem.	0.5	105	68	81	103	124
	1.0	109	73	89	105	127
Methocel $K_{15}M$ prem.	0.5	97	72	95	85	157
	1.0	115	75	88	93	113
	2.0	111	72	96	92	110
Guar gum CSSA	0.5	107	61	77	99	181
	1.0	106	74	101	95	124
	2.0	100	78	91	88	83
Kontroll B	-	98	88	108	122	159

Tabell 12. SAMMENSETNING AV VÅTFÔR[1] TIL FORDØYELIGHETSFORSØK[2] PÅ REGNBUEØRRET.

Tørrstoff (g/kg)	Av tørrstoff		
	Protein (g/kg)	Fett (g/kg)	Aske (g/kg)
359	420	150	70

1) Våtfôret inneholdt 20 g vitaminblanding/kg. (Sammensetning av vitaminblandingen er gitt i tabell 21).

2) Som indikator ble kromoksyd benyttet.

Table 12. COMPOSITION OF MOIST FEEDS 1) FOR DIGESTIBILITY TRIALS 2) WITH RAINBOW TROUT

Dry matter	Of dry matter		
	Protein, g/kg	Fat, g/kg	Ash, g/kg
359	420	150	70

1) The moist feed contained 20 g. vitamin mix/ kg. (The composition of the vitamin mix is given in Table 21)

2) Chromium oxide was used as indicator.

Table 13. APPARENT RECOVERY (%) OF FEED PROTEIN IN THE GASTRO-INTESTINAL CANAL OF RAINBOW TROUT THAT HAD RECEIVED MOIST FEED WITH VARIOUS BINDERS ADDED.

BINDER	Amt. added %	Segment				
		S_1	S_2	S_3	S_4	S_5
Kontroll A	-	88	42	19	16	19
Methocel F_4M prem.	1.0	51	39	34	22	20
Methocel E_4M prem.	1.0	68	49	47	37	42
Methocel K_4M prem.	1.0	88	90	70	41	46
Blanose 7L	1.0	100	44	23	19	18
Blanose $7H_4$	1.0	75	65	38	17	18
CMC-Celcol	1.0	86	52	25	20	25
Natrosol 250 MR	1.0	82	100	73	69	48
Natrosol 250 HR	0.5	72	-	-	30	27
	1.0	99	68	24	25	24
Blanose 7L+Natrosol 250 HR, 1:1	1.0	99	77	47	43	49
Guar gum TH 1	1.0	85	98	59	45	48
Guar gum CSSA	1.0	100	77	53	47	51
K.59.5	1.0	78	100	77	50	-
ADX-72	1.0	81	46	34	33	25
Legacon N	0.5	91	74	52	46	32
	1.0	85	69	70	38	50
Soyakonsentrat Newpro	1.0	82	100	34	28	27
Protatek EFN	1.0	62	96	35	17	20
Kontroll B	-	94	55	27	18	21

Table 14. APPARENT RECOVERY (%) OF FEED FAT IN THE GASTRO-INTESTINAL CANAL OF RAINBOW TROUT FED MOIST FEEDS WITH VARIOUS BINDERS ADDED.

BINDER	Amt. added %	Segment				
		S_1	S_2	S_3	S_4	S_5
Kontroll A	-	80	8.8	2.7	3.7	2.5
Methocel F_4M prem.	1.0	79	26.0	-	31.4	24.6
Methocel E_4^4M prem.	1.0	78	28.2	22.2	32.5	10.7
Methocel K_4^4M prem.	1.0	87	79	42	21.9	16.7
Blanose 7L	1.0	84	8.0	2.9	3.0	2.6
Blanose $7H_4$	1.0	62	27.9	5.0	3.3	2.9
CMC-Celcol	1.0	74	22.6	3.8	3.5	4.1
Natrosol 250 MR	1.0	67	100	62	44	27.1
Natrosol 250 HR	0.5	68	-	-	8.6	8.1
	1.0	79	39.4	6.6	5.3	4.0
Blanose 7L+Natrosol 250 HR, 1:1	1.0	83	86	27.6	18.4	17.5
Guar gum TH 1	1.0	89	67	23.2	17.9	17.9
Guar gum CSSA	1.0	85	47	30.6	21.0	18.3
K.59.5	1.0	62	84	61	25.4	33.7
ADX-72	1.0	100	31.6	13.9	13.5	6.9
Legacon N	0.5	93	77	23.9	15.8	4.8
	1.0	88	35.0	27.7	18.2	25.7
Soyakonsentrat Newpro	1.0	78	50	7.8	4.1	6.3
Protatek EFN	1.0	69	38.9	8.9	4.2	4.1
Kontroll B	-	94	37.6	12.9	5.5	3.5

Table 15. ASH CONTENT IN THE GASTRO-INTESTINAL CANAL OF RAINBOW TROUT FED MOIST FEED WITH VARIOUS BINDERS ADDED.

The ash content is given as g/kg dry matter.

BINDER	Amt.added % (%)	Segment S_1	S_2	S_3	S_4	S_5
Kontroll A	-	210	192	186	204	198
Methocel F_4M prem.	1.0	127	180	198	191	199
Methocel E_4M prem.	1.0	119	159	173	178	178
Methocel K_4M prem.	1.0	133	140	159	169	158
Blanose 7L	1.0	174	171	181	169	176
Blanose $7H_4$	1.0	198	203	205	212	216
CMC-Celcol	1.0	170	187	183	177	171
Natrosol 250 MR	1.0	164	127	147	160	158
Natrosol 250 HR	0.5	167	-	-	188	180
	1.0	175	198	210	230	230
Blanose 7L+Natrosol 250 HR, 1:1	1.0	153	145	155	175	165
Guar gum TH 1	1.0	118	171	185	197	185
Guar gum CSSA	1.0	124	174	211	204	188
K.59.5	1.0	107	117	174	188	164
ADX-72	1.0	98	188	201	212	226
Legacon N	0.5	130	181	188	202	203
	1.0	137	206	201	201	183
Soyakonsentrat Newpro	1.0	191	145	164	174	191
Protatek EFN	1.0	142	168	187	195	174
Kontroll B	-	135	141	157	163	176

Table 16. SUBJECTIVE EVALUATION OF FEED PROPERTIES AND FEED WASTE AFTER ADDITION OF VARIOUS BINDERS FOR MOIST FEED

BINDER	Amt.added%	Feed properties a) (points)	Feed waste b) (points)
Kontroll	-	2	1
Methocel F_4M prem.	1.0	1	3
Methocel E_4M prem.	1.0	2	2
Methocel K_4M prem.	1.0	1	2
Blanose 7L	1.0	1	2
Blanose $7H_4$	1.0	3	2
CMC-Celcol	1.0	2	2
Natrosol 250 MR	1.0	3	2
Natrosol 250 HR	0.5	1	2
	1.0	1	2
Blanose 7L+Natrosol 250 HR, 1:1	1.0	2	2
Guar gum TH 1	1.0	3	3
Guar gum CSSA	1.0	3	3→2
K.59.5	1.0	3	3
ADX-72	1.0	2	3
Legacon N	0.5	2	2
	1.0	3	3→2
Soyakonsentrat Newpro	1.0	2	2→1
Protatek EFN	1.0	2	3→2
Kontroll B	-	2	1

a) 1 point: Sticky feed, difficult to work with
2 points: Relatively good consistency, tendency to stickiness.
3 " Elastic and good consistency

b) 1 point: Large feed loss, particles break apart.
2 points: Feed waste, tendency to breaking up.
3 points: Little (none) feed waste

Table 17. COMPOSITION OF MOIST FEEDS a) USED IN GROWTH TRIALS.

Mixture No.	Dry matter g/kg.	Of dry matter		
		Protein g/kg.	Fat g/kg.	Ash g/kg.
1	306	421	235	65
2	228	594	198	105

a) The moist feed consisted of 93% base feed (60% capelin and 40% pollock), 2% vitamin mix. (Table 21) and 5% binder mix (in this trial the cellulose in the binder mix was replaced with dextrin).

Table 18. RESULTS FROM GROWTH TRIALS WITH RAINBOW TROUT FED MOIST FEED WITH VARIOUS BINDERS ADDED.

There were 60 fish in each group

Tabell 18. RESULTATER FRA VEKSTFORSØK MED REGNBUEØRRET FÔRET MED VÅTFÔR TILSATT ULIKE BINDEMIDLER.

I hver gruppe var det 60 fisk.

Group no.	BINDER (B)	Addition of B, % (%)	No.dead fish fisk	Feed cons(g) (g)	Ave.wt. gain,g. (g/fisk)	Total tilvekst (g)	Feed factor kg feed/ kg.gain
3	Kontroll	-	0	42769	105	6300	6.8
2	Natrosol 250 MR	0.5	0	42246	122	7320	5.8
6	Natrosol 250 HR	0.5	0	38160	108	6480	5.9
1	Legacon N	0.5	0	40056	114	6840	5.9
4	Guar gum TH 1	1.0	1	30964	110	6526	4.7
7	Guar gum CSSA	1.0	1	33635	122	7233	4.7
5	Methocel K_4M prem.	1.0	0	31842	125	7500	4.2
8	Blanose $7H_4$	1.0	7	31358	112	6087	5.2
9	ADX-72	1.0	0	33113	125	7500	4.4
10	Protatek EFN	1.0	0	36140	118	7080	5.1

a) kg fôr/kg tilvekst.

Table 19. SUBJECTIVE EVALUATION OF FEED WASTE IN GROWTH TRIALS WITH VARIOUS BINDERS IN THE MOIST FEED FOR RAINBOW TROUT.

Group no.	BINDER	Amt.added %	Points a)
3	Kontroll		1
6	Natrosol 250 HR	0.5%	1
2	Natrosol 250 MR	0.5%	1-2
8	Blanose $7H_4$	1.0%	1-2
1	Legacon N	0.5%	2
7	Guar gum CSSA	1.0%	3
4	Guar gum TH 1	1.0%	3-4
9	ADX-72	1.0%	4
10	Protatek EFN	1.0%	4
5	Methocel K_4M prem.	1.0%	4-5

a) 1 point: Large feed waste, impossible to see the bottom of the tank after feeding.
b) 2 points: Much sediment, particle size under 1 mm.
c) 3 " Large particles and some sediment.
d) 4 " Large particles but no sediment.
e) 5 " Negligible feed waste

Table 20. ANALYSES OF FISH AT START AND END OF GROWTH TRIALS WITH RAINBOW TROUT USING MOIST FEEDS WITH VARIOUS BINDERS ADDED.

Each group sample consisted of 4 fish.

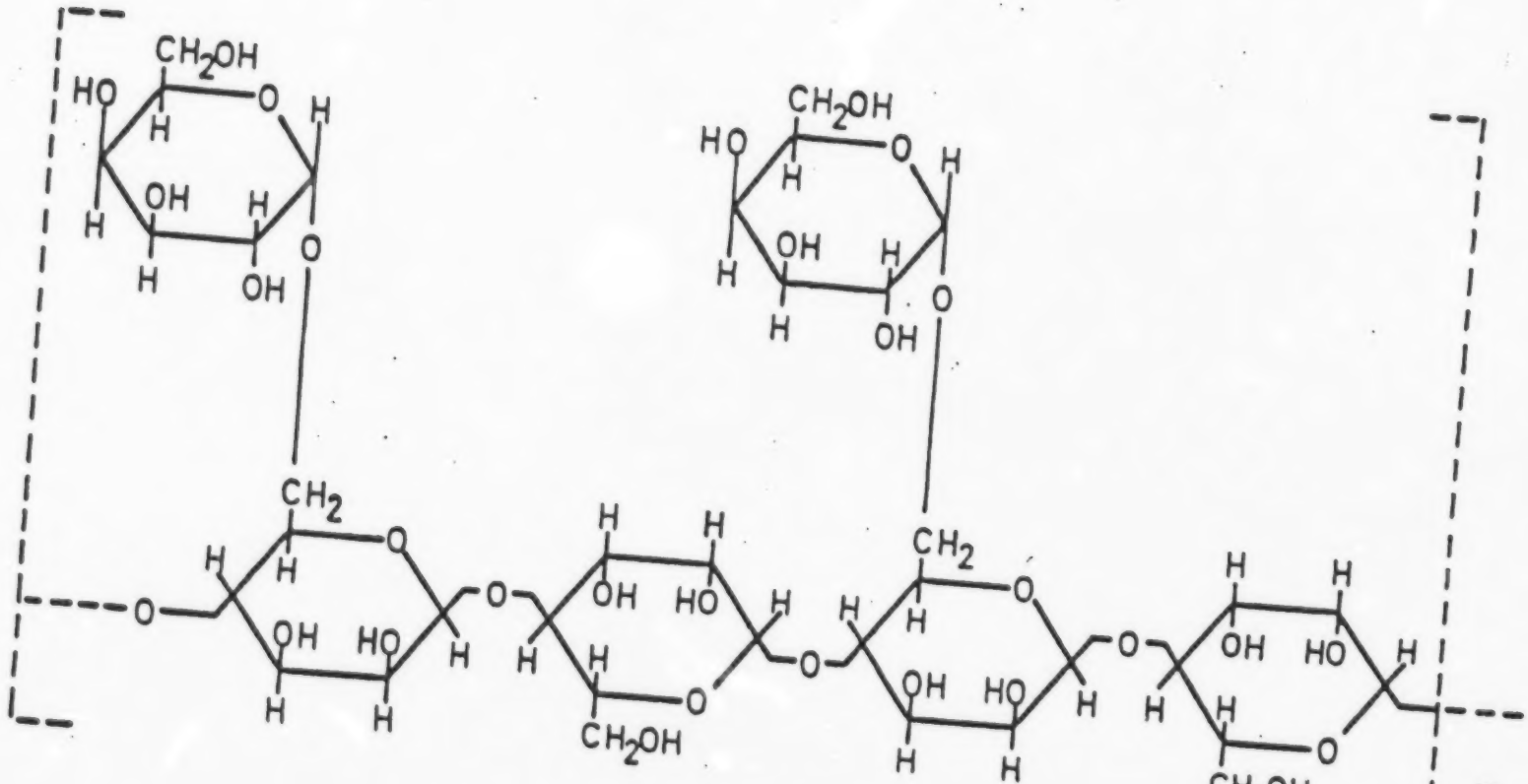
Sample		BINDER	DDEL[1]	Dry matter, g/kg	Of dry matter Protein g/kg.	Fat g/kg	Ash g/kg
Starting fish				310	524	373	64
Fish at finish of trials.							
Gruppe	3	Kontroll		314	469	402	66
"	1	Legacon N		304	481	391	66
"	2	Natrosol 250 MR		302	487	385	67
"	4	Guar gum TH 1		308	488	393	66
"	5	Methocel K_4M prem.		321	448	431	61
"	6	Natrosol 250 HR		313	482	397	69
"	7	Guar gum CSSA		306	488	400	61
"	8	Blanose $7H_4$		314	474	412	64
"	9	ADX-72		304	482	401	64
"	10	Protatek EFN		315	463	424	60

1) 1) The moist feeds had 1% binder added, except the groups with Legacon N, Natrosol 250 MR and Natrosol 250 HR where the addition of binder was 0.5%.

Table 21. VITAMIN MIXTURE FOR MOIST FEED FOR FISH

	mg/kg
Thiamin-HCl	160
Riboflavin	320
Pyridoxin-HCl	160
Folic acid	80
Ascorbic acid	3250
Pantotensyre	640
Inositol	6400
Biotin	16
Niacin	2400
Vitamin B_{12} (0.1%)	320
Rovimix 500/100 (vit. A + vit. D)	64
Vitamin E (50%)	960
Vitamin K, menadion	1280
Dextrinized potato starch	983950

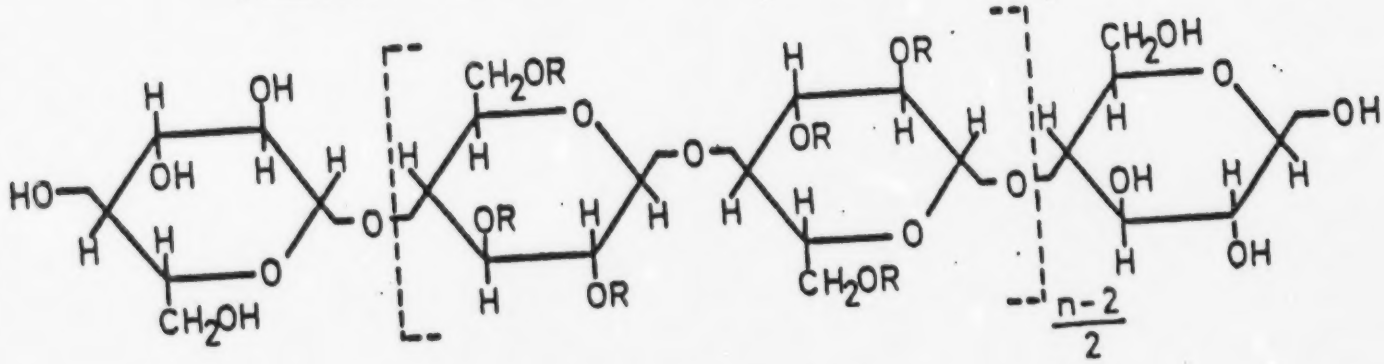
FIGUR 1



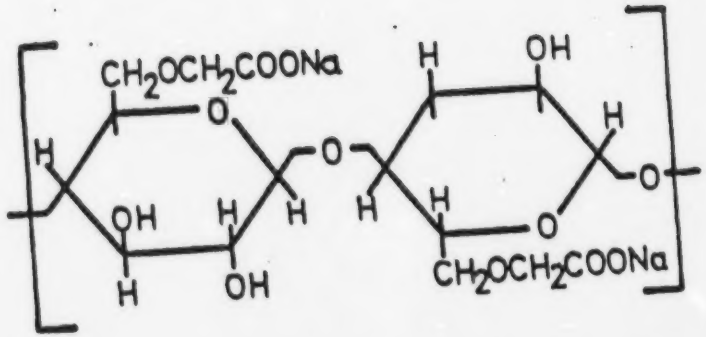
GUAR GUM

FIGUR 2

CELLULOSESTRUKTUR OG ET DERIVAT

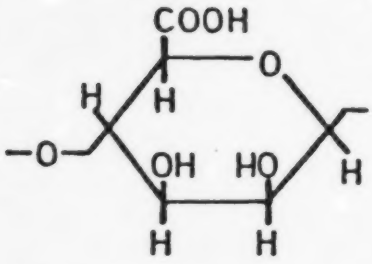


CELLULOSE

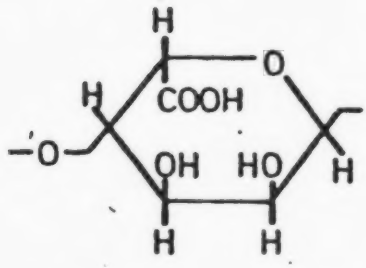


NATRIUMCARBOXYMETHYLCELLULOSE

FIGUR 3

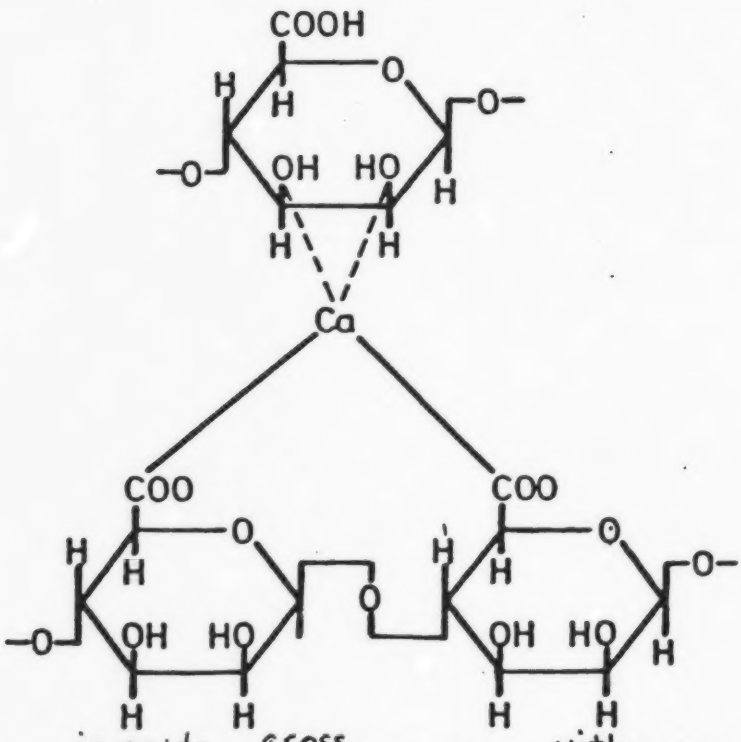


β-D-Mannopyranosyl-
uronsyre
acid



α-L-Gulopyranosyl-
uronsyre
acid

FIGUR 4



Uronsyrers krysbinding med Ca
ic acids cross with

FIGUR 5